Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	
Amendments of Parts 2 and 15	)	ET Docket No. 94-124
of the Commission's Rules to Permit	)	
Use of Radio Frequencies Above 40 GHz	)	RM-8308
for New Radio Applications	)	
	)	

Reply Comments of Hewlett-Packard Co.
In the Matter of Proposed Rulemaking for Frequencies Above 40 GHz

Introduction

1. HP Notes Support for the Millimeter Wave Proposal

We observe that the majority of commentors in this matter have expressed support for the Commission's goals and basic proposals, and that most have made constructive recommendations toward refinement of the proposed rules. We offer specific comments based on our reading of the record in this proceeding, and amend our recommendations accordingly.

2. We Strongly Oppose Vehicular Radar in the Oxygen Absorption Band

A. Six commentors [Mitsubishi, Honda, Fujitsu, Toyota, RCR[1], APMDU[2]] argue for an unlicensed vehicular radar band from 60-61 GHz. HP strongly opposes this for reasons set forth in its original comments: these radars would interfere with broadband communications devices unless given an exclusive band of their own, and granting the band requested would destroy the only contiguous 5 GHz of bandwidth available - or ever likely to be available - for short range broadband communications.

B. Unlicensed mmWave vehicular radars will be not unlike automobile headlights. Their potential for shining on unwanted objects is great, hence interference may well occur between them and nearby devices. Communications devices can solve this problem among themselves by basing equipment design on spectrum etiquette. But they can not talk to radar, so no such spectrum-sharing approach would be possible. In fact, vehicular radar must - for human safety reasons - be assured of continuous, uninterrupted operation. The only practical way to assure this is to give vehicular radar exclusive use of a band, a fact that has been pointed out by many commentors. Therefore, the above six commentors ask the Commission to carve out 1 GHz of spectrum in the middle of the oxygen absorption band for their exclusive use. But 4.2 GHz of spectrum is already being requested by U.S. manufacturers - none of it in the oxygen absorption band - and this should be sufficient for this important new service. Additional spectrum located in the oxygen absorption band offers negligible benefit over this non-oxygen spectrum for vehicular radar, since

1. Research and Development Center for Radio Systems, Tokyo, Japan.
2. Association for Promotion of Millimeter-Wave Development and Utilization, Tokyo, Japan.

close-by vehicles can interfere just as effectively in the oxygen band as in other bands. Vehicular radars must be immune to interference from other vehicular radars in order to work at all. Once this is accomplished, there is no benefit to atmospheric attenuation as provided in the 60 - 61 GHz band.

C. No credible reason for their band selection is advanced by proponents of 60 GHz radar. Honda cites possible future economies of manufacturing scale, but surely, economy of scale is best realized by concentrating products in the European/U.S. bands, for example 76-77 GHz. APMDU cites oxygen absorption as preventing radar interference with "cars approaching at a distance." But what about cars close by? Toyota states: "Since automobiles move around, interference with other radio facilities might occur." Indeed! This is why most commentors call for exclusive bands for vehicular radars. In fact, European standards already call for 76-77 GHz for vehicular radar. Non-European firms wishing to export their vehicles to Europe will be forced to comply with this standard. Why not make this standard international? Vehicular Radar manufacturers would benefit from such an outcome.

D. If the Commission were to decide to allow vehicular radar in the precious 59-64 GHz oxygen absorption band, all hope of using this resource for broadband communications as part of a national information infrastructure would be lost. If the Commission were to grant the 60 GHz vehicular radar proponents' request, and convert 60 - 61 GHz from general unlicensed to vehicular radar, *efforts of U.S. and other companies to develop broadband communications systems would probably be abandoned.* U.S. and European radar manufacturers have wisely requested frequency spectrum outside the oxygen band. Why should an exception be made for a non-standard frequency based on a particular radar development? The public interest would be poorly served by such a decision.

E. We strongly urge the Commission to deny this request for a Vehicular Radar Band at 60 - 61 GHz, and to write rules which clearly prohibit radar-like devices in general unlicensed bands.

3. We Amend our Recommendation on Vehicular Radar Frequencies

Based on the amended requests of U.S. automakers, we support moving the 139-140 GHz radar band to 152-154 GHz. We propose moving the band requested by Vorad, Inc. to 45.5 - 45.7 GHz, as explained in our detailed spectrum plan, below.

4. We Urge Rapid Action on 40.5-42.5 GHz LMWS

There is substantial interest from many commentors for opening the 40.5-42.5 GHz band to LMDS-like service. We reiterate our support for this option, and note that it seems to be free from opposition, which argues for swift action by the Commission. Timely resolution of the spectrum conflict over LMDS would benefit all parties, we believe, so we urge the Commission to settle the issue quickly. We join the majority of commentors in pointing out that the 40.5 - 42.5 GHz band should not be subdivided into units of less than 1 GHz of contiguous spectrum per licensee. We repeat our claim that the principal advantage of millimeter waves is the broad transmission bandwidth it affords: subdivision would destroy this benefit.

5. We Note Consensus on Passive Sensing Interference Issue: There Is No Problem

In addition to our detailed comments on the matter, comments by the National Academy of Sciences' Committee on Radio Frequencies [CORF], and the National Aeronautics and Space Administration [NASA] validate the viewpoint that terrestrial transmissions in the 56-64 GHz

oxygen absorption band will be no problem for spaceborne passive sensors. Since our original filing, it has come to our attention that some ground-based atmospheric temperature sounding applications make use of frequencies in the 50-60 GHz range.[3] However, such work has long been carried out in the 20-30 GHz frequency range, where FCC-licensed transmitters abound. Work in these lower frequencies has occasionally caused problems for ground-based scientists, due to received interference from licensed transmitters, but these problems can be overcome by experimental technique.[4] Interference with passive sensors should be much less of a problem in the oxygen absorption band, where propagation distances are shorter. *We urge the Commission to consider this passive sensor interference issue closed.*

6. We Oppose Mandatory Spread Spectrum in 59 - 64 GHz Band

In its comments, Epsilon Lambda Electronics Corporation calls for unlicensed spread-spectrum communications in the 59-64 GHz band. We certainly support spread spectrum as one alternative for unlicensed communicators, but wish to be very clear on the following point: the Commission should not mandate any particular form of modulation in this unlicensed band. Rules should concentrate on methods for minimizing interference only. We believe that a so-called "spectrum etiquette" could address the interference problem without requiring any particular modulation scheme.

7. Spread Spectrum Should Be Subject to the Same Power Limit as Other Modulations

As to power levels for spread-spectrum communicators, we assert that spectrum spreading is not known to offer any radiological safety benefits, as compared to CW signals of the same total power at the same center frequency. Therefore, a 1-Watt spread spectrum transmitter would present just as much of a challenge from the radiological safety point of view as would a CW transmitter. Commentors have asked for 10 to 16 dBW EIRP for unlicensed devices. We urge the Commission to adopt this EIRP standard, rather than the 1-Watt transmitter power standard proposed by Epsilon Lambda, in order to limit the interference range of unlicensed communicators [See appendix B].[5]

8. *Premises Communication* Should Be Supported in the 59 - 64 GHz Band.

Several comments[6] imply, in our opinion, an interest in what might be called *Premises Communication:* short-range, high-bandwidth, point-to-point and network communication. We believe that *Premises Communication* will be the most popular and valuable use for the unlicensed 59-64 GHz band. We urge the Commission to develop rules which support *Premises Communication* in the 59 - 64 GHz band. Examples of *Premises Communication* include: Wireless Local Area Networks, Campus-wide Links, Roadway Communications, and the like. We believe that with a properly-designed spectrum etiquette, different system designs and standards can be accommodated within the same frequency band, and that the benefits of high bandwidth thus obtained will offset the slight risk of interference between unlicensed *Premises Communicators*. We note that a useful spectrum etiquette does not now exist, and that it is important for the Commission to

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3. Ulaby, F.T. et al., "Microwave Remote Sensing," Artech, 1986 vol. III, Chapter 17.
4. Christopher Ross, Pennsylvania State University, private communication.
5. Appendix B was inadvertently omitted from our initial filing, but filed post-deadline to rectify the error. For those who may not have seen the later filing, we include the appendix here.
6. HP Laboratories, Metricom,Inc., Epsilon Lambda Electronics, Hughes Aircraft, Millimeter Wave Advisory Group.

endorse the concept soon, so that interested parties in the communications community can proceed in earnest to develop a spectrum etiquette.

9. We Urge Careful Consideration of Point-to-Point Communications Needs

Several commentors[7] have expressed interest in point-to-point broadband links. The Commission should give very careful consideration to their views. All these commentors agreed with the HP position that additional licensed spectrum should be made available. ANS, TIA, and Harris call for a licensed band 55.2 - 58.2 GHz. HP proposed a licensed band 56 - 58.2 GHz. We join with these commentors in urging the Commission to develop such a band for point-to-point links, and we urge the Commission to preserve the 59 - 64 GHz band for lower-power unlicensed applications, such as Premises Communication.

10. Lack of Interest Argues for Delaying Rules for Bands Above 100 GHz

No interest has been expressed in frequencies above 100 GHz, except for the vehicular radar request at 152-154 GHz. Therefore, we reiterate our advice to the Commission: delay setting rules and assigning bands for frequencies above 100 GHz (except for vehicular radar), until experience is gained at the lower frequencies and a demand develops.

11. No Interest Expressed for Satellite Communications Above 40 GHz at Present

Despite much comment from organizations interested in satellite communications,[8] no comments seem to propose rules which would favor satellite-ground communications in the frequencies above 40 GHz. We infer from this that there is presently little or no interest in satellite communications in these bands, and that rulemaking should concentrate on multipoint distribution, point-to-point communication, premises communication, and vehicular radar.

12. Little Interest Expressed in Unlicensed Bands Above 64 GHz

While many commentors, including HP, favor a balance between licensed and unlicensed services, we feel that lack of specific proposals for unlicensed services above 64 GHz argues for delaying rules in those frequency ranges. Several commentors point out the need for preserving large blocks of contiguous bandwidth, and even proposals for 1 GHz may not be sufficient for future needs. Therefore, we urge the Commission to concentrate on developing rules for the frequency bands below 64 GHz, except for the cases of vehicular radar, where specific requests exist at the higher frequencies.

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7. Hughes Aircraft Co., Telecommunications Industry Association, Alcatel Network Systems, Harris Corporation

8. See: Hughes Communications Galaxy, TRW, Teledesic, GE Americom, Martin Marietta, Rockwell, NASA, comments in this matter.

12. We Propose A Band Plan Based on Comments and Interest Expressed

A. The 40.5 - 42.5 GHz band proposal for LMWS has received near-unanimous support, and should be adopted immediately

B. As proposed by TIA, Alcatel, and Harris, the VORAD Vehicular Radar Band should be relocated in the 45 - 47 GHz band. We propose 45.5 - 45.7 GHz.

C. Provided that sufficient interest develops from potential developers, we propose the band 46 - 47 GHz be earmarked for unlicensed spread-spectrum communications. The 1 GHz bandwidth should allow sufficient bandwidth for broadband mobile services, for example. By requiring spread-spectrum [in this band only], the Commission could protect against interference in a band where oxygen absorption does not limit range. A 300 MHz "guard band" would separate this band from the vehicular radar band mentioned above, thus reducing the constraints on out-of-band interference.

D. The bands 47.2 - 50.2 GHz, 54.25 - 56.2 GHz, and 71 - 74 GHz provide opportunity for expanded multipoint distribution service of the LMDS type (should this be required), and/or fixed point-to-point licensed services. Commentors in support of one or both of these services include: HP, TIA, Alcatel, and Harris. The Commission should establish rules for at least one of these bands immediately.

E. As we proposed in our earlier direct comments on this matter, frequencies from 56.0 - 58.2 GHz provide the range-limiting properties of oxygen absorption, and would be appropriate for one or more licensed bands. In particular, these frequencies might be appropriate for short-range point-to-point links in cellular-like systems, where frequency re-use is desired over kilometer distances. Given the interest in point-to-point links expressed by several commentors, along with the necessity to wisely plan the use of the oxygen absorption band, we urge immediate action on our proposal. However, should the Commission wish to divide the 54.25 - 58.2 GHz band evenly, a division centered at 56.2 GHz would seem appropriate, allowing 2 GHz inside, and 1.95 GHz outside, the oxygen absorption band.

F. We urge the Commission to take immediate action on our proposal for a General Unlicensed Band 59 - 64 GHz, which is the only internationally-allocated 5 GHz of contiguous spectrum within the oxygen absorption band. The comments espousing vehicular radar in this band should serve as a warning of what would happen were the Commission not to act *now* to protect the full 59 - 64 GHz for broadband communication.

G. We urge immediate adoption of the Vehicular Radar Bands detailed in the spectrum plan.

H. Due to lack of interest at present in General Unlicensed Bands above 64 GHz, we modify our proposal, and urge the Commission to delay rulemaking for these frequencies until such time as interest in these frequencies develops.

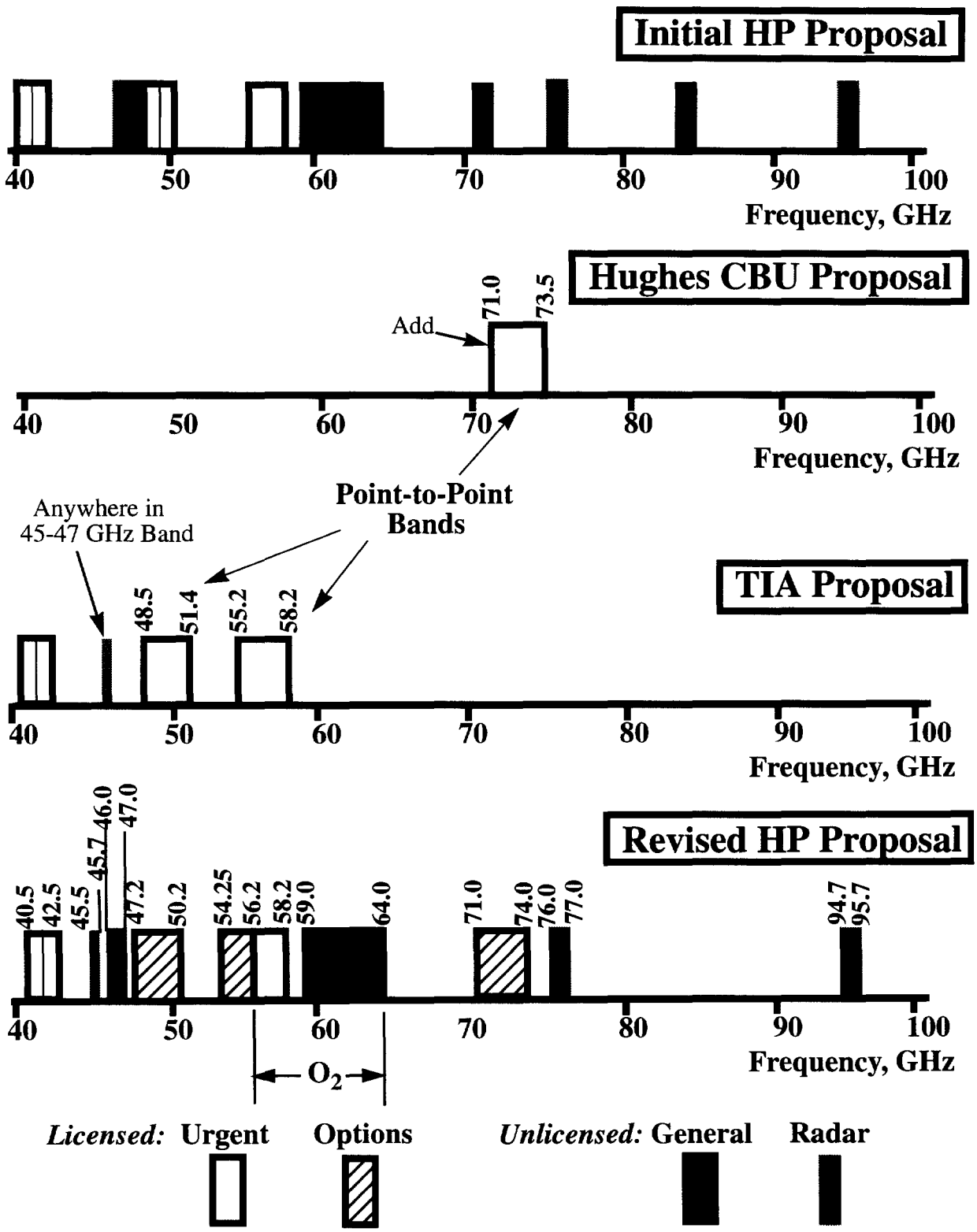
Table 1: Revised Frequency Plan

Frequency Band	U.S. Allocation	Revised HP Proposal
40.5 - 42.5 GHz	Broadcast, Fixed Mobile	LMWS, 2 Licensed Bands
42.5 - 43.5 GHz	Fixed, Mobile, Astronomy	None
43.5 - 45.5 GHz	Government	None
45.5 - 45.7 GHz	Mobile, Radionavigation	Vehicular Radar
46 - 47.0 GHz	Mobile, Radionavigation	Unlicensed Spread Spectrum
47.0 - 47.2 GHz	Amateur	None
47.2 - 50.2 GHz	Fixed, Mobile	Licensed, Medium-Range
50.2 - 50.4 GHz	Passive Satellite Fixed Mobile	None
50.4 - 51.4 GHz	Fixed, Mobile	None
51.4 - 54.25 GHz	Passive	None
54.25 - 56.2 GHz	Fixed, Mobile, Passive	Licensed, Medium-Range
56.2 - 58.2 GHz	Fixed, Mobile, Passive	Licensed, Short-Range
58.2 - 59 GHz	Passive	None
59 - 64 GHz	Fixed, Mobile, Radiolocation	Unlicensed Premises Com.
64 - ... 71 GHz	Various	None
71 - 74 GHz	Fixed, Mobile	Licensed, Medium-Range
74 - 76 GHz	Various	None
76 - 77 GHz	Radiolocation, Amateur	Vehicular Radar
77 - ...94.7	Various	None
94.7 - 95.7 GHz	Fixed, Mobile, Radionavigation, Radiolocation	Vehicular Radar
95.7 - 152 GHz	Various	None
152 - 154 GHz	Fixed[a]	Vehicular Radar[a]

a. We note the incompatibility with present U.S. and International Allocations

Vehicular Radar: 3.2 GHz Licensed: 6.95 - 11.95 GHz Unlicensed: 6.3 GHz.
Total Spectrum Proposed: 16.45 - 21.45 GHz

Comparison of Proposals, 40 - 100 GHz:



13. Commentors Want Higher Power Limits, Relaxed Spurious Response Rules

A. A number of commentors - including HP - have requested higher power limits for licensed and unlicensed services. We include in these Reply Comments a copy of Appendix B from our original filing, for reference. With respect to the oxygen absorption band, it is our judgment that +10 dBW EIRP should be allowed, but that in no case should higher powers be allowed in this band. The reason is this: the chief virtue of the oxygen absorption band [56 - 64 GHz] is its ability to limit interference distances to 1-2 km. To "blast through" this natural blanket with higher powers would be an inappropriate use of this natural resource.

B. Hughes Communications Galaxy, Inc. makes an excellent point regarding transmitter power. It is possible, especially with TWT amplifiers, to design a multifrequency system in which multiple "channels" pass through one physical amplifier and antenna. It would also be possible to design a system using multiple transmitters, each at a lower power, but with the same power-per-unit bandwidth as the TWT case. We recommend that the Commission allow TWT transmitters [in licensed bands only] on the basis of a "power-per-channel" criterion up to a maximum of +36dBW total power per installation. This would allow for 100 "channels", each with +16 dBW EIRP.

C. Hughes Aircraft Co. Communications Products Business Unit [HCBU] makes the point that extremely high-directivity antennas are available in the millimeter wave frequency bands, and that such antennas could be usefully employed in point-to-point links. They cite the example of a 1W transmitter with 50dBi antenna as a practical scenario. HCBU argues for an EIRP limit of +50 dBW based on this reasoning. We urge the Commission to allow such installations on a case-by-case basis in licensed bands only, and to set power limits accordingly

D. Several commentors point out the difficulty of suppressing out-of-band emissions to levels below -30 dBc with low-cost equipment. However, as we point out in Appendix B, -30dBc out-of-band spurious responses - even those from +16 dBW vehicular radar - could conceivably cause problems for systems operating in other bands. Since General Unlicensed Bands are afforded no regulatory protection against interference (under Part 15 rules they must accept all interference), the Commission should make every effort to protect these bands against spurious emissions from other bands *now*, before equipment is designed and in place. We believe such protection could be provided with little difficulty for the following cases:

1. Licensed transmitters in any or all of the bands proposed in our *Revised* Band Plan would have adequate "guard bands" separating them from unlicensed bands [200 MHz, minimum], so that a 50dBc limit on emissions *from* these licensed transmitters *into* the unlicensed bands would be practical.
2. Similarly, Vehicular Radar transmitters are adequately separated from unlicensed bands [300 MHz, minimum], and a 50 dBc limit on emissions *from* these radars *into* the unlicensed bands should pose no problem for the radar transmitters.
3. The two Unlicensed bands are separated by 12 GHz. Emissions from one of these bands into the other should be no problem.

Therefore, we propose a two-tier set of rules for spurious emissions: -30 dBc into licensed bands, -50 dBc into unlicensed bands. We further suggest that license holders should expect freedom from interference in their band. In the rare event where such interference comes from out-of-band spurious emissions, the offending transmitters should be required to lower emissions. Details are shown in the following table:

Table 2: Summary of Recommended Power Limits

Transmitting Band ->	General Unlicensed	Unlicensed Radar	Licensed
Average EIRP	+10 dBW	+16 dBW	+16dBW[a]
Out-of-Band Spurious Emissions ***into*** General Licensed Bands [b]	-14 dBW	-14 dBW	-14 dBW
Out-of-Band Spurious Emissions ***into*** General Unlicensed Bands	-34 dBW	-34 dBW	-34 dBW

a. Except for the 56-59 GHz band, this power may be increased to +36 dBW in the case of multifrequency transmitters, or to +50 dBW in the case of high-directivity antennas. However, spurious emissions would remain as shown above.
b. If the table value causes actual interference to any licensed service in another band, the interfering transmitter must reduce spurious emissions to a level where no interference is caused, or to -34 dBW, whichever is the greater power level.

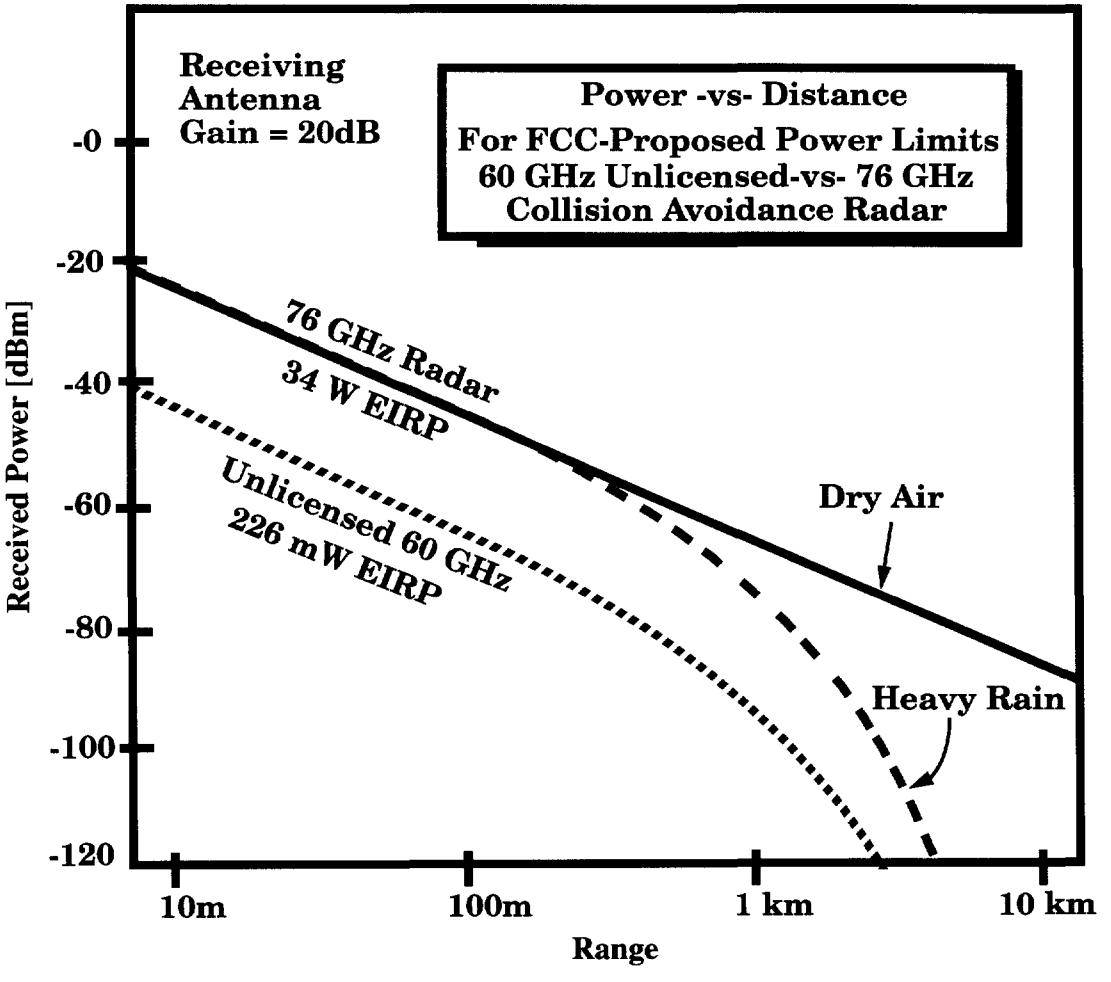
14. We appreciate the opportunity to comment in this matter, and hope to continue to work with the Commission and other interested parties to refine the millimeter wave spectrum use proposal.

Appendix B:

Unlicensed Transmitter Power Limits for the O_2 Absorption Band

Background:

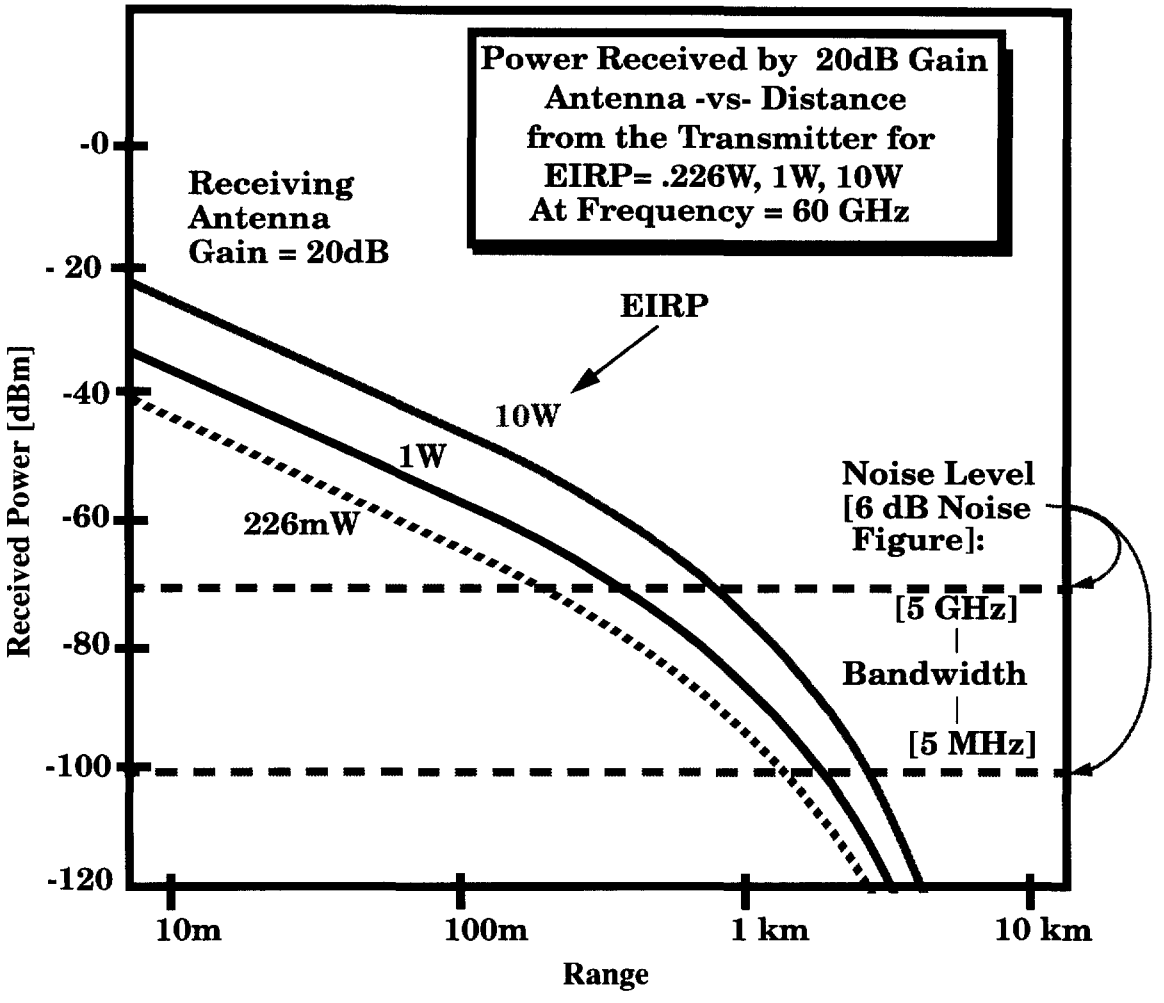
The NPRM [Paragraphs 38 and 47] proposes much higher power limits for unlicensed collision-avoidance radar than for general unlicensed devices. If we compare the power-vs-distance [Free space, no multipath] for collision avoidance radar at 76 GHz to a general unlicensed device at 60 GHz, we see that the radar signal propagates farther, having a potential for causing interference at a much greater distance - perhaps at distances greater than 10 km.



Yet industry tests show that the radar power limit proposed here "...would allow development of effective radar equipment and, at the same time, minimize the potential for harmful interference." [NPRM Paragraph 47]. We have no reason to dispute these findings, and are prompted to examine the issue of propagation characteristics for general unlicensed devices.

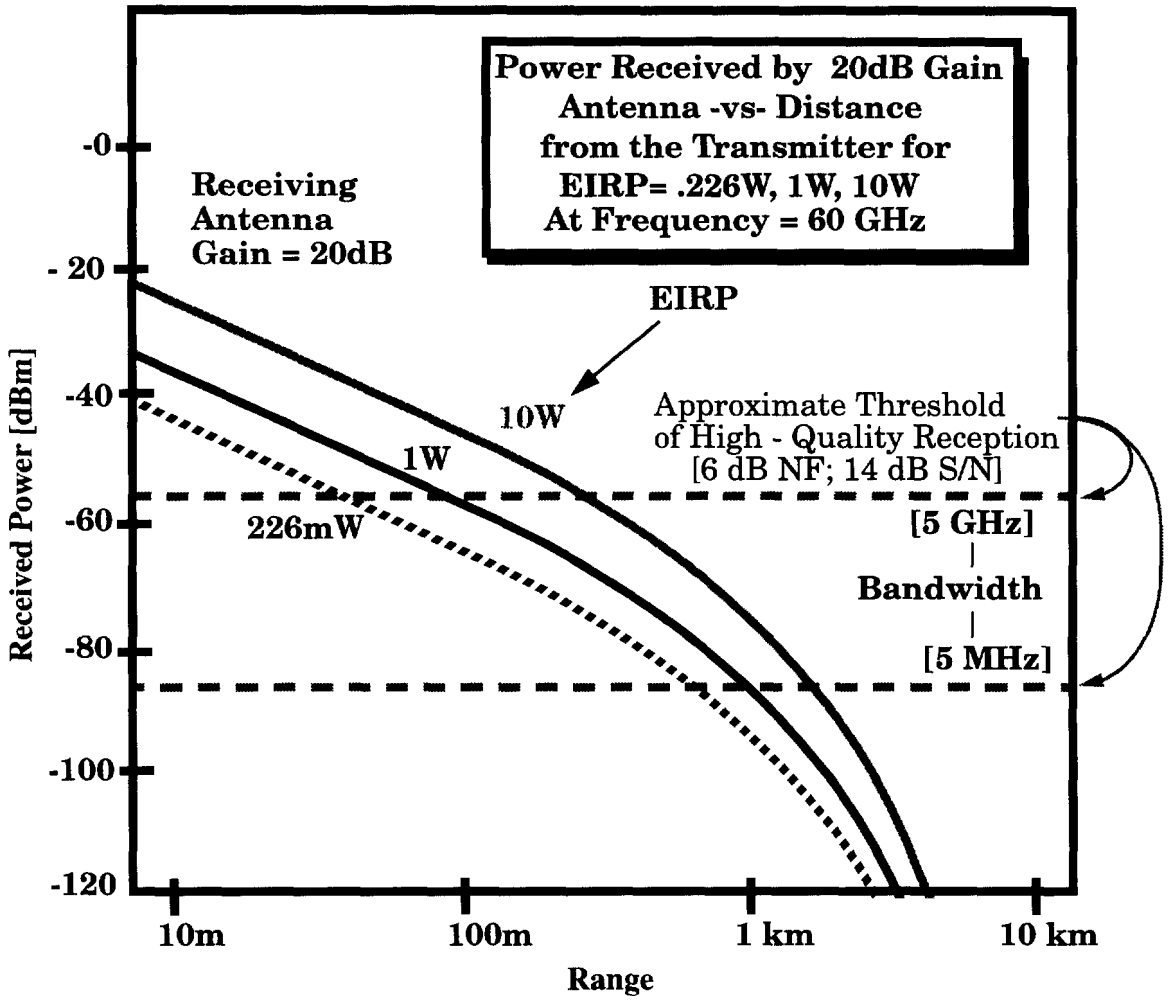
What is Range of Potential Interference?

If we plot the idealized power-vs-distance curve for a 60 GHz line-of-sight transmission at several different EIRPs on the same graph with noise levels for two different receiver bandwidths, we can get some idea of what the "interference range" might be in the case line-of-sight with no multipath, no obstacles, and no attenuators other than oxygen [assumed 10dB/km here]:



We see that the proposed 226 mW EIRP [equivalent to 200 nW/cm^2 @ 3m] is theoretically capable, under these idealized conditions, of causing interference in a 5 MHz bandwidth receiver at a distance of 1.4 km. If the EIRP is increased to 10W, this distance increases to 2.8 km. Thus, a 40x increase in EIRP leads to only a 2x increase in interference range. In the extreme case of a receiver with 5 GHz bandwidth, the interference distances would be much shorter, because receiver noise is higher. In actual practice, the interference distance would likely be less than shown above, but the relative effect of raising power would be the same: slight. Since 10W EIRP could be readily obtained - for example, with a 10 mW transmitter and 30 dB gain antenna - and since the penalty in interference range would be small, why not increase the EIRP limit to this value?

But before reaching a conclusion, we need to ask the question: how much power will be needed for a reasonable range? If we modify the above graph to include thresholds for reception for the 5 MHz and 5 GHz cases, allowing for a 14 dB S/N ratio, we get some idea of what the useful line-of-sight range could be, under ideal conditions (no heavy rain, no multipath, no obstructions).



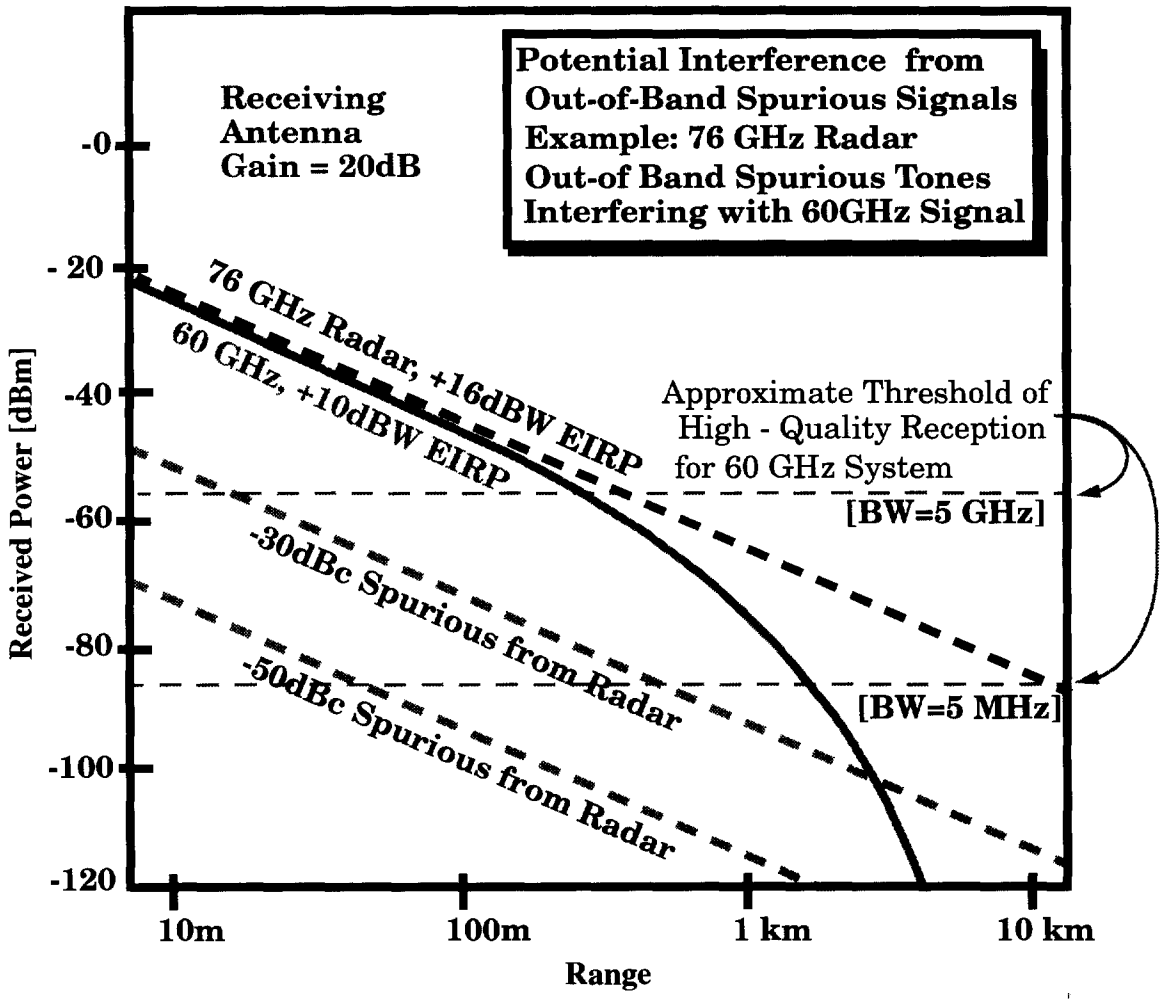
We see a dramatic range improvement with increased transmitter power for the broad bandwidth case: for 5 GHz BW, range increases from 40 meters to 275 meters when we increase EIRP from 226 mW to 10 W. Since broadband communications are one of the major potential applications for mmWave transmitters, this would seem to be a major benefit.

Summary of Range Discussion

In the 59-64 GHz band, increasing EIRP from the proposed 226 mW to 10 W is practical, and carries with it as much as a 7X improvement in range, with a worst-case interference range increase of only 2X [1.4 km to 2.8 km]. Collision-avoidance radars as proposed would have 34 W EIRP, and when judged by similar criteria would have ranges in excess of 10 km. As a matter of judgment, and for consistency between general unlicensed transmitters and unlicensed collision avoidance radars, we recommend increasing the power limit in the O_2 absorption band [56-64 GHz] to 10 Watts EIRP.

Out-of-Band Spurious Emissions

A limit of 50 dB below carrier has been suggested as a limit for out-of-band spurious emissions from unlicensed devices. Below, we apply this standard to the proposed +16 dBW power limit for vehicular radar, and examine how this spurious emission level might affect a 60 GHz broadband communication system. We compare spurious emission levels of 50 dBc and 30 dBc, to see whether the limits could be relaxed.



Conclusion:

Spurious emissions from vehicular radar could be a problem for 60 GHz communication systems, if those spurious emissions fall within the 60 GHz system bandwidth and are only 30 dB below the maximum radar EIRP. However, a 50 dB specification seems tolerable.

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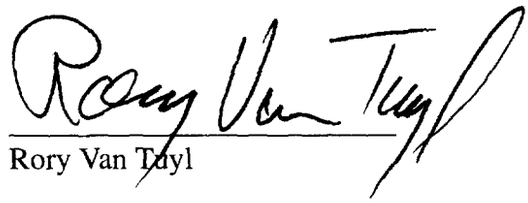

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